have appropriate safeguards to prevent air intake from starting a severe reaction.

Proper instrumentation should be provided to warn of inlet/exhaust filter blockage and loss of pressure/containment. Pressure gauge/transducer line filters (Section 7.2.5) should be used to protect this instrumentation.

HEPA filters have been used on gloveboxes to contain radioactive materials since the early days of the nuclear industry. History has shown that, as a rule, this has been adequate; however, submicron-sized particles of some materials can pass through HEPA filters. In such cases, it is critical to have knowledge of the material properties. Technology should be used to help understand the type of filters and efficiencies that can be used for a proper filtration system.

In short, the glovebox ventilation and filtration system must be capable of reliable performance to assure glovebox operators that they may safely operate the box without fear of exposure to airborne contamination to themselves, other facility personnel, and the environment.

7.2 Design of Glovebox Ventilation Systems

The principals of glovebox containment are very basic. Experience has shown that an airflow of 100 fpm through a breached (8-in. diameter) glove port will maintain containment. This is an inherent (defined as "real time, at the moment of failure") safety feature that should be incorporated into the glovebox system. Most nuclear, biological, and pharmaceutical facilities in the United States are designed to provide this capability (within a range of 10 percent). It is important to understand how this is achieved.

A glovebox is basically a closed volume. When the blower unit draws air (negative side) from the box, the box is under negative pressure. The filters help regulate this pressure. Filters are basically controlled leaks that allow airflow through them while trapping the particulates they are designed to filter out. The inlet filter establishes the actual glovebox working pressure, while the exhaust filter system establishes the inherent safety feature. It is therefore critical for the exhaust filter to be properly engineered into the system to perform its inherent duty. When a glove port breach occurs, by design the inlet filter is bypassed and the breached glove port becomes the inlet.

The air change rate is an important consideration for all gloveboxes. As glovebox volume increases, airflow should increase. However, the inherent safety feature of 100 fpm through a glove port must be maintained. For normal operations, flow rate is based on the dilution of evolved combustible or corrosive gases and heat dissipation, and is often based on prior experience (see Sections 7.2.1 and 7.2.2). The exhaust capability must be sufficient to provide safety under postulated abnormal conditions, including the glove port breach.

Operating personnel, industrial hygienists, and radiation specialists can assist the designer in establishing realistic requirements, particularly when an existing system is being replaced or revised. The types and quantities of materials to be used inside the box and their toxicity and state (wet slurry, dry powder, etc.) must be considered when establishing the air exchange rate and velocity. When exposed radioactive material is handled inside a glovebox, the box becomes the primary containment. When handling nuclear and pyrophoric materials, consideration should be given to whether pressure inside the glovebox should be positive or negative. A positive-pressured glovebox provides a motive force for airborne contamination to leak from the box into the secondary containment (the facility). Negative pressure inside the box is essential to maintain glovebox containment when working with radioactive material. In an application where an inert environment is used to control fire and explosion, the box may be slightly positive or even neutral, and the facility becomes the primary containment. This suggests the need for a secondary containment and also flags the need for PPE and appropriate procedures to protect the worker. The designer must design for failure, i.e., using the worse case scenario, the designer must predict the consequences of a glovebox failure.

7.2.1 Blowers

The blower is the motive force which provides the pressure and airflow requirements in a glovebox. Although the related principles are covered in

Chapter 5, glovebox blower requirements have different or additional requirements. Generally, the airflow is very low (<100 cfm) for most applications. It should be noted that this is true for gloveboxes with volumes of less than 100 ft^3 and does not factor in heat or gas loading as described below. Selection of the blower must account for not only the breached glove port scenario, but also corrosive gases and filter loading.

The typical airflow for most gloveboxes is 35 cfm, assuming a standard 8-in.-diameter gloveport. A typical cartridge filter rated at 35 cfm will have an approximate 0.8 in.wg clean static pressure drop. When both inlet and exhaust filters are installed, the total pressure differential for the filter requirements is 1.6 in.wc. This does not factor in the ductwork and inlet configurations described in Chapter 3. The filter loading factor for most facilities is sometimes greater than double the initial static pressure. In this situation, the blower must be able to perform within its blower curve at 1.6 to 3.2 in.wc and still produce 35 cfm. This is higher pressure and lower flow than most fan and blower applications. A regenerative blower is often used in this application. These blowers operate similar to pumps in that the clearance between the blower wheel and blower housing is very small. If the blower is to service more than one glovebox, the blower should be sized to handle the additional requirements. Exhaust manifolds should use dedicated lines for each glovebox to prevent transfer of heat from one glovebox to another.

Regardless of the type of blower or manufacturer, the required airflow and pressure requirement must be attained for safe operation of a glovebox. Another criterion for blower selection and design is selection of a blower that does not exceed the pressure limits of the glovebox. Depending on their size, most 7-gage wall stainless steel gloveboxes are designed and tested at -4 in.wg. Exceeding this pressure may cause damage to the glovebox windows, seals, and shell. If the blower exceeds this limit, the glovebox should be equipped with a pressure relief device (see Section 7.2.5).

"Pressure recovery" is a term that evolved from quick insertion and removal of operators' arms into and out of the gloves. Although the blower will deal with most of the volumetric changes caused by glove movement, loading the exhaust filter will prevent the blower from quick recovery. Exhaust filter and glove port sizes also influence recovery. This is the reason for maintaining the inherent safety feature at the design phase of a glovebox project. If larger glove ports (greater than 8-in.-diameter are selected, the site-specific "standard" filter housing and filter will not address the need for more airflow.

Blower location depends on several variables in glovebox applications. If a scale or other vibration-sensitive device is used in the glovebox, the blower should be isolated from the glovebox shell with vibration isolators and a flexible inlet/exhaust connection. Although this works in most applications, some may require remote location of the blower away from the glovebox. Blower noise should be considered to prevent annoying the workers. Noise levels should be kept to less than 80 dB(A).

7.2.2 FILTER HOUSINGS

It is imperative that the filter housing on a glovebox be designed to function correctly. It should incorporate designs for safety, ergonomics, and reliable operation. Filter change-out should be simple and should maintain a safe level of containment. The design should prevent any form of contamination from reaching the downstream ductwork or secondary containment (the facility). The design should satisfy the ergonomic requirements of filter changes and allow the operator to perform the operation safely (without exposure or injury). In most installations, the filter housings are located in areas of the glovebox that are awkward to reach. Top-mounted filter housing should be as close to the front of the glovebox as possible and should be aligned with a glove port. Although DOE-STD-1066-99[30] suggests locating the exhaust filter housing to a lower position in the glovebox for fire purposes, this may cause a loss of containment in some applications. Process activities and materials could block the exhaust filter. Without the exhaust filter airflow, it would be difficult to maintain containment. The filter housings on gloveboxes differ from most filter housings in that they are very small due to ergonomic limitations and low airflow requirements. Changing a glovebox filter is difficult since it must be performed through a glove port with limited operator movement. Use of larger filters should be avoided because they are difficult to handle safely inside a glovebox without special tooling.

7.2.2.1 TYPES

The types of filter housings selected for use on gloveboxes have always been application-specific. As many nuclear facilities function under different directives, filter housings have evolved to suit their respective applications. Early gloveboxes often had externally mounted HEPA filters. Because of the potential for spreading contamination during filter changes, this practice should be avoided.

Internal filter installations range in design, however, and all have a mechanism to restrain the filter, a HEPA filter, and a sealing mechanism. These mechanisms also vary; however, it is critical that the mechanism be free of sharp edges that can easily cut gloves. Cracks and crevices should be kept to a minimum since the location makes cleaning difficult. Filter housing construction typically requires clean, smooth finishes to allow cleanup of contaminated or potentially contaminated areas. Experience has shown that areas that are exposed to contamination can be impossible to clean. The rougher the surface of the housing, the more difficult it is to clean. Valves, located to the outside, are used to isolate the spent filters during filter changes. Most applications use a prefilter to protect the HEPA filter and a fire screen when there is a potential for fire. Although diverse, the many designs of prefilters and fire screen designs should meet the requirements imposed in DOE-STD-1066-99.[30]

The last basic requirement is a means and method to remove the contaminated filter from the glovebox. The most common method is the bag-in/bag-out method (see Section 7.2.2.4).

Push-through filter housings differ in that they hold the standby filter in the filter housing. The filter is a cartridge type with Chevron seals located at the inlet and the exhaust of the round cartridge filter. It has advantages in that it is designed to maintain containment during a filter change. The spent filter is displaced with a new filter by pushing it through. The old filter and spacer are displaced to the inside of the glovebox. The inner pipe "tube" of the housing is honed to obtain a smooth, round surface. The Chevron seal, being larger than the internal diameter of the tube, creates the seal. Although this system has been used with great success, seal quality and tube finish are critical to its proper operation. The vulnerability of this filter housing design lies in its use for applications involving light, easily airborne materials. Such materials, if surface deposited on the inside tube, can bypass the seals during a filter change because the seal can "rollover" the material. Another potential drawback of this design is its orientation. It should be installed in a vertical position for proper sealing. A horizontal installation will enable the seals to take a set and eventually bypass the filter. This filter housing has been used at many nuclear facilities in the United States for many years with good reliability; however, be aware of its limitations.

Cartridge filters can be used for glovebox operations for both radioactive and nonradioactive applications. These filters incorporate the filter housing and filter as a single unit and are supplied from the manufacturer with options for pipe nipple connections on both the inlet and exhaust or on one end only. Test ports should be specified when ordered, as these filters range in size and airflows. A prefilter should be installed inside the glovebox because the cartridge filter is not equipped with this provision. On nonradioactive or nonhazardous applications, an isolation valve should be located between the glovebox and the filter for removal and isolation during change-out. In radioactive applications, the cartridge filter should be located on the inside of the glovebox for safe changing of the filter. The isolation valve should be located on the outside of the glovebox.

Bag-in/bag-out side-access filter housings are used in some glovebox applications. They are available in sizes from 35 cfm on up and in rectangular or round configurations, as discussed in Chapter 4. In these applications, it is desirable to mount the housing as close to the glovebox as practical. Long ducting or plenum runs are not desirable due to the lack of access for cleaning. Mounting the filter housing directly to the glovebox reduces the potentially contaminated surface area.

Redundant filter housings (**FIGURE 7.3**) are used when working with materials that, if released through the exhaust system, would be catastrophic with respect to both safety and associated cleanup costs. While all nuclear facilities use a secondary exhaust before discharging to the outside air, this method is a known as a "belt and suspenders" approach. In some older facilities, manifold systems were not designed for safe, clean decontamination. If contamination migrates into these systems' ducting, cleanup is both costly and time-consuming. As a result, consideration should be given to a redundant filter. The design of a redundant system requires the use of an in-place-tested primary and secondary HEPA or ultra-low penetration aerosol (ULPA) exhaust filter installation. Although ANSI-N-509[31] describes the features of testing redundant filter banks, it is not specific to redundant glovebox housings. The illustration has one filter changed from inside the glovebox (primary), and the another (secondary) is shown as a bag-in/bag-out type changed from the outside.

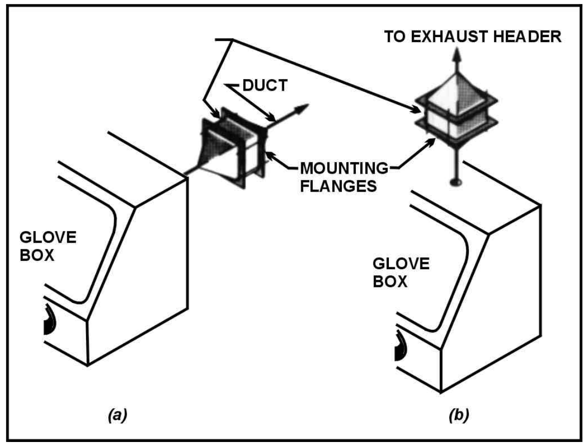

Figure 7.3 – Redundant filter housings

7.2.2.2 MATERIALS

It is important to understand the construction materials used on the filters and filter housings for gloveboxes, particularly chemical processing gloveboxes. It should be clearly understood which chemicals and gases will be introduced into the airstream of the glovebox and where they will be processed if processing is required. If a bag-in/bag-out port is used, the bag material is subject to the same exposure to chemicals and gases as the rest of the ventilation. Simply put, the materials, ducting, blower unit, etc., must be compatible with the chemicals and gases exposed to the exhaust airstream.

Filters are available in many different materials for different purposes. Wood, several different stainless steel and aluminum materials, etc., are commonly selected for different applications. Recently developed technologies such as stainless steel, ceramic, and PTFE filter media have outstanding resistance to chemicals, heat, and gases. However, these recent developments have not gained wide acceptance in nuclear applications.

7.2.2.3 IN-PLACE TEST PORTS

The size of a glovebox filter housing is relatively small compared to most filter housing installations. As with any HEPA filter installation, test ports should be placed on the filter housing to validate the installation. The criteria for testing gloveboxes focus on the proper location to inject the challenge aerosol, upstream, and downstream samples. The test ports should be designed to be sealed after each use and to be as cleanable as possible. This is usually a 3/8- to 1/2-in. half-coupling with the appropriate plug. The weld and finish of a test port should emphasize clean smooth surfaces, especially from the inner diameter of the port to the filter housing. Cracks and crevices in this area are next to impossible to clean via access through glove ports.

7.2.2.4 BAG-IN/BAG-OUT PORTS

Bagging ports are used on gloveboxes for multiple purposes such as transferring materials and equipment and removing the waste generated during operations. Significantly, they are also used to transfer new or spent filters while maintaining containment. It is important to size the bagging port to accomplish this purpose, and it is desirable to use a cylindrical bagging port because this design is much more operator friendly. A typical bagging port should have two outer-raised ribs around the outer circumference to prevent the bag from being easily pulled off during operations. The ribs are normally raised approximately 1/4 to 3/8 in. above the outer circumference and 1.5 in. apart. A safety-restraining strap should be used to prevent the bag from being easily pulled off. It should be installed whenever the bagging port is being used, and removed only when performing the bag-in/bag-out (new bag installation) procedure. The strap is secured between the two ribs. A cinching strap may be used to prevent the bag from being sucked into the glovebox due to negative pressure. It is installed when the bagging port is not being used. An internal access door may be used to isolate pressure surges and to act as a secondary containment for the bag. The door should have a seal to prevent egress of contamination from the glovebox. An external cover may also be used to protect the bag keep it out of the way of other operations. A "bagging kit" should be supplied with a bagging port. It should contain the components, tools, and procedures to perform the operation. These items are covered in Section 7.4.

7.2.2.5 SEALING MECHANISMS

There are multiple sealing methods for filter housings and filters used on gloveboxes. These can be application-specific or site-specific and are either gasket- or fluid-sealed. The designer should consider chemical, gas, radioactivity, and heat as deciding factors in determining which sealing mechanism to employ. In some applications, the filter housing is welded and incorporated into the glovebox. In others, the filter housing is a bolted, gasketed installation. The bolted design is more versatile by design, however, a potential crack at the gasket interface may make decontamination difficult. It should be noted that a push-through filter housing should be bolted due to the housing manufacturing process. Filter seals vary by application. HEPA filters can be supplied with many different gaskets and fluid sealing systems.

7.2.2.6 BLOWER CONNECTIONS

If a dedicated blower is to be installed on a glovebox, there are several installation considerations such as vibration, exhaust connection configuration, and blower discharge configuration. It is generally accepted practice to use a flexible connection in most ventilation applications; however, DOE Standard 1066-99[30] outlines the need for fire protection and the requirements associated with the installation. Vibration from the blower will transmit to the filter housing and subsequently to the glovebox. If a flexible connection is used to isolate vibration from the blower, there is a potential for heat damage to the connector. It is recommended that noncombustible materials be selected for this application. Blower designs vary. Selection of the exhaust and inlet connection should prevent severely affecting the blower capacity. Obstructions at the immediate inlet and outlet will grossly affect the blower capacity. Elbows and tees at the inlet will also affect capacity and should be avoided.

7.2.3 DILUTION OF EVOLVED GASES

A high air exchange rate is often required to dilute fumes generated in an air-ventilated glovebox. When evolved gases, vapors, and particles are not flammable, toxic, or corrosive, flow rates sufficient to maintain a negative pressure, with differentials from 0.3 to 0.5 in.wg in the box, may be employed. However, when fumes or vapors are hazardous, a higher ventilation rate is necessary. The maximum generation rate of hazardous substances must be determined to establish the minimum airflow rates needed for dilution. The following equations can be used to determine minimum safe airflow rates.[3]

$$Q = \frac{R\,(10^6)(S),}{L} \qquad (7.1)$$

where

Q = required dilution flow rate, cfm

R = contaminant generation rate, cfm

S = safety factor (4 to 10 is suggested, depending on volatility, flash-point temperature, degree of mixing, and risk)

L = limit value of contaminant, volume parts per million (vpm) [use threshold limit value (TLV) for toxic vapors and lower explosive limit (LEL),[4] converted to vpm, for combustible vapors].

If the contaminant vapor is evaporated from a liquid, the contaminant generation rate, R, can be determined using the rate of liquid evaporated where:

$$R = \frac{W}{M}\,(359)\;\frac{t + 460}{492} \qquad (7.2)$$

W = liquid evaporation rate, lb of solvent/min

M= molecular weight of contaminant

t = air temperature, degrees Fahrenheit

Equation (7.2) above assumes that a pound mole of gas will occupy 359 ft^3 at 32 degrees Fahrenheit and standard pressure. The dilution flow rate, Q, in Equation (7.1) assumes that the dilution air is free of the contaminant under consideration; otherwise, the background concentration of the contaminant in the dilution air (in vpm) must be subtracted from the limit value, L, in the denominator.

Concentration gradients can easily be formed during rapid vaporization if the hazardous gas is much lighter or heavier than air and there is poor mixing; safety factors above 7 should be used in such cases. For example, 1 lb of acetone evaporated in a box in 1 hr requires a dilution rate of 5.1 cfm multiplied by the safety factor, S, to ensure dilution below the lower explosive limit.[6] Since acetone evaporates rapidly and has a flash point of zero degrees Fahrenheit and an LEL of 2.2 percent, a safety factor of 10 should be used. In operation, as little as possible of a solvent like acetone should be permitted in the glovebox at any one time. It should be assumed that the entire contents could be spilled, thus creating an event. Consideration should also include feed-throughs where flammable liquids and gases are pumped or released into the glovebox environment. The feed lines should be constructed of materials that are resistant to the gas or liquid. It is preferable for these lines to be hard-piped to the glovebox, although this is not always practical. An isolation valve should be provided to shut off the feed system in an emergency. It is preferable to use an automated failsafe feature, with appropriate sensors, if the equipment located inside the glovebox is not explosion-proof. This is also preferable when the equipment is not monitored for long periods.

7.2.4 HEAT DISSIPATION

It is important to understand the importance of heat removal as it applies to ergonomics. Operators access the inside of the glovebox using gloves that are often awkward to use and glove ports that limit the operations. When higher than normal heat conditions exist in a glovebox, it becomes very annoying and leads to higher fatigue levels. This then becomes a limiting factor on the operations to be performed in the glovebox environment. For worker comfort, sufficient air should be exchanged through the box to limit the inside temperature to no more than 15 degrees Fahrenheit above room temperature. When the calculated airflow rate for cooling exceeds the exhaust cfm, consideration should be given to higher airflow (larger filters or more filters), supplementary cooling, better insulation of heat sources, cooling coils, or chill blocks for hot materials. In the design phase of a glovebox project, the designer should be aware of the heat load presented by the equipment that must be located in the glovebox. It is desirable, when practical, to determine whether items like electric motors can be placed to the outside of the glovebox. This can reduce the heat load inside a glovebox significantly, and also simplify maintenance and serviceability and reduce disposal costs. Operations to be performed in a glovebox should be determined ahead of time. Airflow velocities can affect the operation of sensitive equipment and cause materials like powders to become airborne. [It should be noted that negative pressure also can cause equipment problems.] There are practical limits to the amount of cooling that can be accomplished by airflow, since high airflow rates can create strong air currents if not properly diffused. Where possible, operators should be protected from objectionable sources of radiant heat by surrounding the heat source with reflective shields or conductive jackets. Exhaust air streams may be routed through such shields to permit the maximum pickup of convected heat before leaving the box.

When the heat load to the glovebox has been determined, the required cooling airflow rate to dilute the hot gases is calculated using the following equation.

$$Q = \frac{H,}{C\,(t_2 - t_1)} \qquad (7.3)$$

where

Q = airflow, cfm

H = sensible heat change (by convection), Btu/hr (1 W = 3.41 Btu/hr)

t_1 = temperature of entering air, degrees Fahrenheit

t_2 = desired average air temperature inside box, degrees Fahrenheit

C = conversion factor for sensible heat change for air, Btu/(cfm x hr)(degrees Fahrenheit) = (density) (specific heat) (60 min/hr)

Both the density and specific heat of air at room conditions depend on the humidity ratio of the air. The density also depends on the temperature. In a room at 75 degrees Fahrenheit and 50 percent relative humidity (RH), the air density is 0.073 lb/ft^3 and specific heat is 0.24 Btu/lb. Therefore *C* is 1.1 Btu/ (cfm)(hr)(degrees Fahrenheit) and Equation (7.3) becomes:

$$Q = \frac{H}{1.1\,(t_2 - t_1)} \qquad (7.4)$$

Long-term operation of high-heat-producing equipment can damage filters when exhaust air temperatures approach the temperature limit of the filters for continuous exposure to heat (see TABLES 3.5 and 3.6).

7.2.5 EMPIRICAL FLOW RATES

It is important to design the ventilation system to provide a safe, ergonomically practical, and reliable unit. Experience has shown that filter pressure drops will vary, ductwork loss will be greater, and blower performance may be slightly different in actual working conditions (other variables also are discussed in this chapter). If the glovebox ventilation system does not perform as designed, it should not be used or commissioned until it meets the minimum safety requirements of this document and other referenced documents.

Troubleshooting an installation should include the inspection of the ductwork and installation of the blower (including wiring); the prefilter, inlet, exhaust HEPA filters; and the manifold (if equipped). Common problems with new installations include debris lodged in the ducting, blower housing, and filter housing. Long flexible connections will also affect the performance since a bend can dramatically choke off airflow. It also is not uncommon to find the blower motor wiring reversed.

7.2.6 EXHAUST REQUIREMENTS

The maximum airflow rate from the glovebox determines the required capacity of the filters and the size of the equipment for the entire downstream portion of the ventilation system. The airflow resistance of the exhaust-air path must be sufficiently low so that the pumping of gloves (pressure recovery) by operators in the box will not result in positive pressurization. In small, low-flow boxes such as those with inert atmosphere, pressure surges due to glove pumping may be a serious problem. Fast insertion of the gloves can cause the glovebox to reach a zero or positive pressure. Although this is typical for most applications, another method called "passive recirculation" can be used to retain the inherent safety feature and larger filters for air cleaning functions. It should be noted that this method should not be used with pyrophoric materials since, during a glove breach, the inert environment will be lost. The glovebox is fitted with an inlet and exhaust filter as is typical in a room air application. Another filter "emergency discharge" is added and fitted between the blower discharge and the inlet air filter. The blower installation connects the exhaust filter housing to the negative side of the blower and the inlet filter installation connects to the positive side. When the installation is complete, the emergency discharge filter is in a standby condition. The ventilation unit basically recirculates the inert gas. If a breach or leak occurs, the emergency discharge filter becomes naturally activated. The path of least resistance during a breach discharges exhaust air through the emergency standby filter, since the inlet is now the glove port. This filter should also be sized for the glove port "inherent safety feature." The filter should be rated for twice the cfm or half the pressure drop of the inlet filter. If the two filters, inlet and emergency standby, have the same airflow and pressure drop, the airflow will be directed to both instead of the emergency standby filter. If air is to be exhausted from the emergency standby filter, a bleed vent is necessary to prevent removing the inert gas and imposing additional negative pressure. When the glovebox ventilation unit is activated, there should be no flow through the emergency standby filter. If the secondary exhaust system is directly connected without a bleed vent, the glovebox pressure will become extremely negative. The vent allows room air to be removed until the emergency standby filter requires exhaust.

The maximum rate of exhaust flow from a room-air-ventilated glovebox is usually based on the required inlet flow when a glove is ruptured or inadvertently removed. The air velocity into the open port should be 100 fpm or greater. Good contamination control is more easily achieved in a glovebox having low air leakage. Gloveboxes should have leakage of less than 0.02 percent to 0.5 percent box volume/hr, depending on the application requirements. In some applications, such as inert environments, a helium leak test is performed to assure the integrity of the glovebox. The method, technique, and criteria for testing are given in the ASME AGS "Guideline for Gloveboxes, AGS-G001," Section 9.11.4.[28]

7.2.7 Vacuum- and Pressure-Surge Relief

In some applications, gloveboxes must be protected against physical damage resulting from excessive pressure or vacuum. The exhaust and inlet supply system must be able to handle slowly manifested pressure or vacuum disturbances. Each glovebox containing service connections or internal equipment whose malfunction might cause a pressure surge should be equipped for prompt surge relief. This also applies to fire suppression systems, as outlined in DOE STD 1066-99.[30] The response time and pressure-flow characteristics of the surge-relief device will depend on the flow and pressure characteristics of the pressure source, the free volume, and the relative strength of the gloves and glovebox. The relative strength is defined as the lowest pressure differential that will cause rupture of the glovebox pressure boundary at its weakest point. Depending on the design of the box, the weakest point will usually be a window or a glove. The surge-relief device can be a liquid-filled U-tube, as shown in **FIGURE 7.4**. The surge-relief flow capability should exceed the flow from the largest possible source of pressurization at the design relief pressure. The HEPA-filtered surge-relief line should not be connected to a glovebox exhaust manifold because this line will be subjected to the same pressure as the normal glovebox exhaust connection. For the relief device in FIGURE 7.5, a liquid storage reservoir is provided to handle the blown seal fluid. The filter and ductwork should be sized in accordance with the required cfm and pressure drop based on the pressure surge. The filter should be protected from impingement of the seal fluid. If room air cannot be tolerated in the glovebox, as is the case in some inert-atmosphere applications, a different vacuum surge-relief system must be used. A U-tube can be devised to restore its seal after relieving the surge, but such a system must include a feature to alert the operator that a pressure surge has occurred so that he can make the necessary safety checks. An inlet filter may provide surge relief if no backflow device or other restriction is provided. The filter-face area would have to be about four times the area of an unfiltered port to achieve an equal venting effect.[11] [Explosion venting is not covered in this handbook.]

7.2.8 Glovebox Exhaust Manifold

A glovebox exhaust manifold is used when multiple gloveboxes will share a common ventilation system. This method reduces the amount of exhaust ventilation components for dedicated exhaust systems. The glovebox exhaust manifold includes all of the glovebox exhaust system downstream from the point where the exhaust from two or more gloveboxes joins and the airflow is combined. Sections 7.2, 7.3, and 7.4 of this chapter discuss details of the exhaust system and illustrate working examples.

The glovebox exhaust manifold draws air or exhaust gas from each connected glovebox at a controlled pressure and airflow (interdependently), houses secondary treatment facilities, and transmits the air for further treatment or exhausts it to the outside atmosphere. Primary exhaust treatment should be applied inside or as close to the glovebox as possible and, in all cases, before connection of the exhaust line to the exhaust

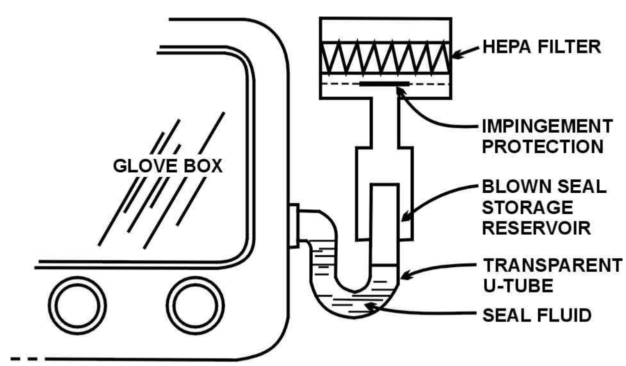

Figure 7.4 – Glove box vacuum-pressure surge relief device

manifold. It is critical to protect the manifold from contamination due to the difficulty of cleaning and decontamination. In some systems, a portion or most of the cleaned or treated exhaust gas may be recirculated back to the gloveboxes.

[Note: The manifold system should be sized and controlled to accept a range of flow whose high extreme is the sum of (1) the maximum normal flow from each box (Sections 7.2.1, 7.2.2, and 7.2.3), (2) the largest maximum flow under removed glove conditions from one of each of five connected boxes (Section 7.2.4), and (3) an allowance for system growth. The low extreme is the sum of the minimum flows from each box. An allowance for system growth should be provided at not less than 20 percent of (1) plus (2) above for a new system. If this allowance exceeds 50 percent of (1) plus (2), other provisions such as installing an equivalent dummy flow should be considered.

7.2.9 Exhaust Cleanup Requirements

As Low as Reasonably Achievable (ALARA) exposure to radioactive material is the guiding principal for determining the design of a glovebox ventilation unit. Protecting the exhaust downstream of the primary HEPA filter is paramount for nuclear installations. Experience has shown that exhaust systems are not only difficult to decontaminate, but have led to operator exposures. It is also true that, after filter breakthrough, nuclear particles can migrate to all the gloveboxes in the chain. As discussed earlier in this chapter, a filter installation is only as good as the entire ventilation system.

When corrosive gases or vapors are in the exhaust airstream, all of the filters in a series will be exposed. The widely held impression that the life expectancy of a group of HEPA filters arranged in series is directly proportional to the number of filters in the series may be false when chemical or heat degradation occurs. Under these conditions, when the first stage fails, there is a potential for others to fail from the same cause. Corrosive gases and mists from vats, scrubbers, and similar equipment must be neutralized and removed before they reach the HEPA filters.

Installation requiring redundant HEPA filters must have provisions for in-place testing. The requirements are provided in ASME N-510[32] and ASME AG-1, Section TA.[29] If chemical detection systems are required due to possible filter installation damage, the monitoring system should be HEPA-filtered to prevent damage to the instrument. Many manufacturers supply testable filters of this type. These should be specified with upstream and downstream test ports. The filter flow should be consistent with the monitoring instrument airflow.

7.3 Glovebox Filter Installations

For the most part, the glovebox filter systems discussed in this section are first-stage (primary) HEPA filters, although redundant filters located upstream from the exhaust manifold (if equipped) connection are also discussed.

Filters must be able to perform properly when they are either clean or dirty. A maximum dirty-filter resistance of three times the clean-filter resistance for HEPA filters and two times the clean-filter resistance for prefilters is generally used for design purposes. **FIGURE 7.5** gives the approximate airflow and pressure-drop relationships for clean open-face HEPA filters. **FIGURE 7.6** shows common locations for HEPA filters near or inside gloveboxes. Type 2C shows the installation of inlet and exhaust filters inside the glovebox.

7.3.1 HEPA Filters

A detailed discussion of filter performance and construction materials is given in Section 3.2.

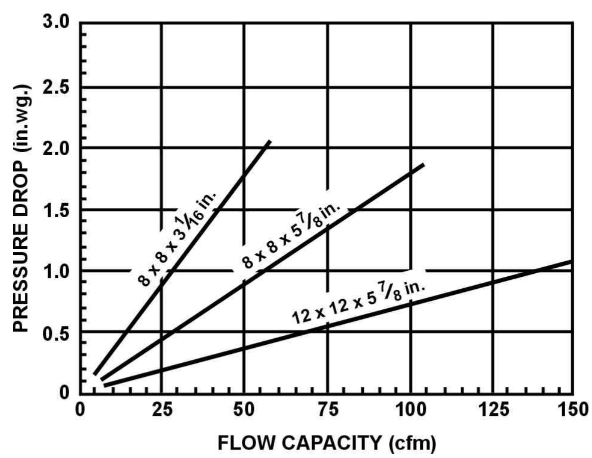

Figure 7.5 – Flow vs. pressure drop relationship for small, clean, open-face HEPA filters